Overview of NOAA HD-SP2 Science Objectives for SEAC4RS

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Overview

In SEAC4RS we flew a Humidified Dual Single Particle Soot Phototmeter (HD-SP2) rack on the NASA DC-8 research aircraft. This unique instrument consists of two Single Particle Soot Photometers (SP2s) operating in parallel and sampling primarily off of the dry aerosol feed from the Univeristy of Hawaii aerosol inlet. One of the SP2s was operated dry while the other was humidified to constant RH typically near 90%.

The dry SP2 provides, for individual particles in its detection range, the optical size, refractory black carbon (rBC) mass, and rBC mixing state of individual particles. These quantities are integrated in post-processing to provide rBC MMR and a Mie-theory based estimate of the amount of non-rBC material internally mixed with rBC. These outputs provide handles on many SEAC4RS science topics, some of which are presented here.

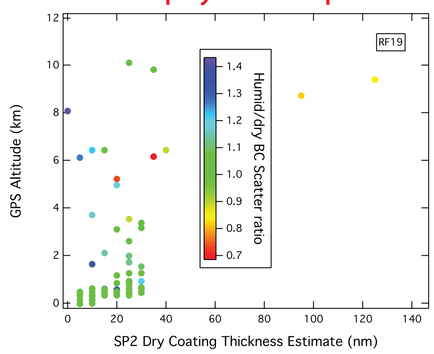
The wet instrument provides the same outputs for individual particles, but reflecting the uptake of water by the materials internally mixed with rBC. Hence, comparison of the optical size distributions associated with rBC between the wet and humidified samples constrains water uptake, with implications for BC aging, optical properties in the ambient, potential to act as CCN, lifetime, and thus radiative impact.

In SEAC4RS we also deployed a flat-plate 90 degree interstitial sampling inlet that had proved valuable in cirrus when flown on the WB-57F high altitude research aircraft.

Here we present and overview of the validation of the HD-SP2 measurements, the performance of the 90 degree inlet, and science goals associated with BC vertical profiles, BC microphysics, BC cloud interactions, and water uptake by BC-contiaining particles. We are also interested in pursuing and supporting analysis of BC emission factors, contributions to total absorption, source apportionment, and model validation.

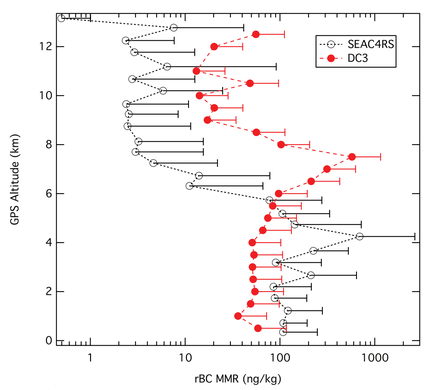
BC Vertical Profiles

Microphysical Properties



Here we show water uptake (90%) for RF09, as a function of observed coating thickeness (SP2 estimate) and GPS altitude. Deciphering trends in coating thickness and water activity with altitude will both elucidate the mechanisms affecting BC lifetime, and bound model estimates of enhanced absorption by BC.

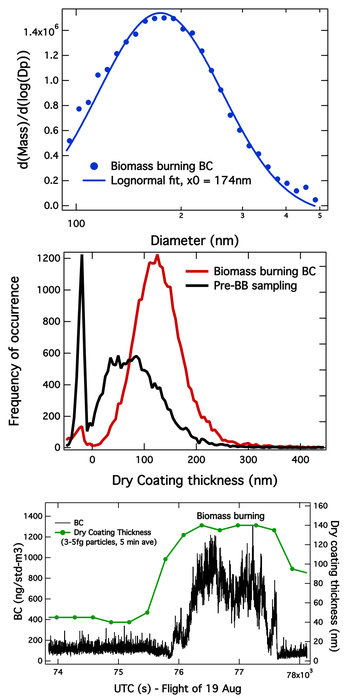
Convective Transport



Black carbon vertical profiles: mission averages from DC3 and SEAC4RS. In DC3 high rBC loadings throughout the free troposphere appear to be caused by large scale regional processes.

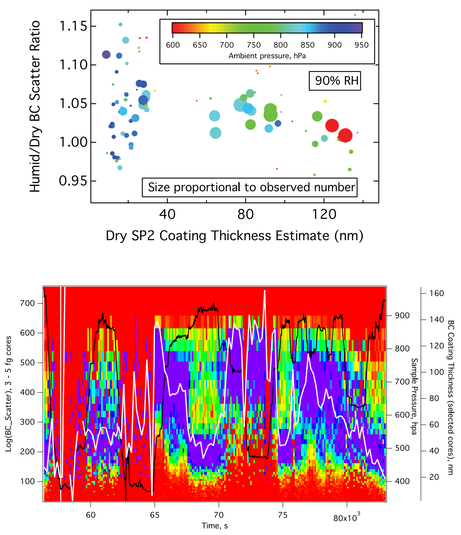
BC Microphysical State and Evolution

Plume Characterization



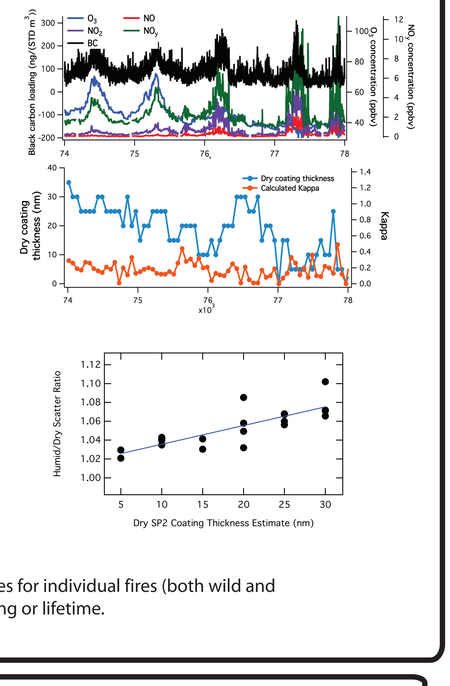
RF04: Low water uptake

RF04 (SE chemistry/convection) provides a good example of the basic tenor of results achieved with the humidified/dry measurement. Although we sampled diverseair masses with radically different BC microphysical state, only very small changesin water uptake were revealed on this flight.



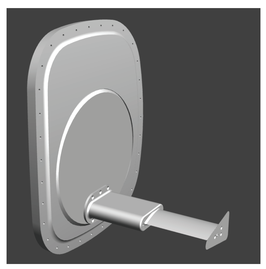
RF19: Evolution of Houston outflow

Aging of urban outflow is associated with increasing coating thickness on BC cores. However, there is very little evidence of significant changes in water activity of the coatings. These results, largely representing fossil fuel BC, will be contrasted with those from measurements of BC from wild and agricultural burning.



We intend to examine rBC size distributions, mixing state, and associate with water-active speicies for individual fires (both wild and agricultural) to explore systematic differences in these parameters with implications for BC forcing or lifetime.

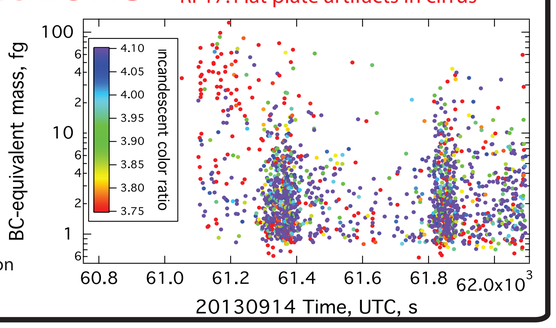
Interstitial BC/Cloud Interactions



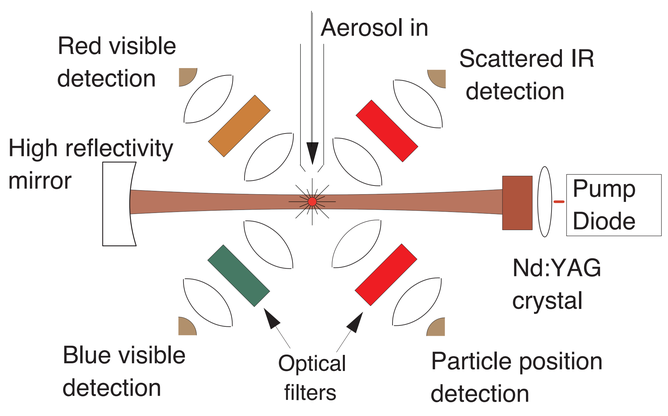
The flat-plate inlet allows 90 degree sampling from the air flow. Although it proved useful for interstitial sampling in cirrus when flown on the belly of a WB-57F research aircraft, SEAC4RS results were not as satisfying

The flat plate inlet showed clear signs of artifacts in cirrus:
1) changes in particle size distribution
2) changes in incandescent particle color temperature
3) "pulses" or "spurts" of particles consistent with reaerosolization of particles by ice crystals striking a hard surface

RF17: Flat plate artifacts in cirrus



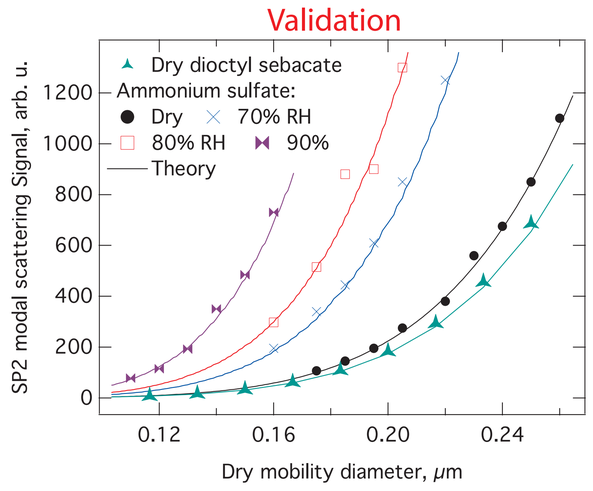
HD-SP2 rBC Measurement



An gaussian intracavity laser (1 μm) iheats rBC particles, first vaporizing internally mixed materials, and then heating rBC to its vaporization temperature. The visible light thermally emitted is proportional to its rBC mass. Light scattered from the laser can be analyzed for evidence of vaporization of internally mixed material and for the optical size of the whole, unperturbed particle.

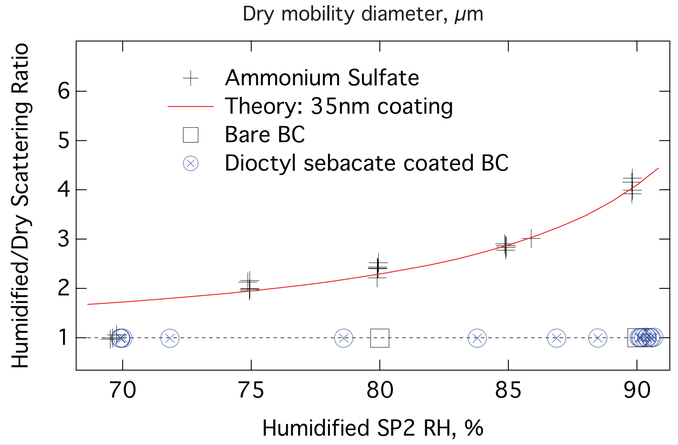
The two SP2s (humid and dry) were calibrated for laser intensity/scatter detector gain via independent calibrations, and via LARGE-group calibrations during flight. Additionally, we have explored using scattering off of bare rBC cores, just prior to incandescence, to cross-calibrate the two measurements of scattering.

Validation



Humidification validation with homogeneous laboratory aerosols: PSLs, ammonium sulfate, and dioctyl sebecate.

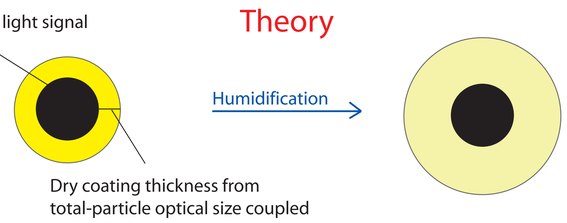
Mie scattering was integrated over the SP2 solid angle of detection. kappa-Köhler theory was used to predict particle size and index of refraction. The excellent agreement validates both the humidification measurement, and the detection of humidified aerosol by the SP2.



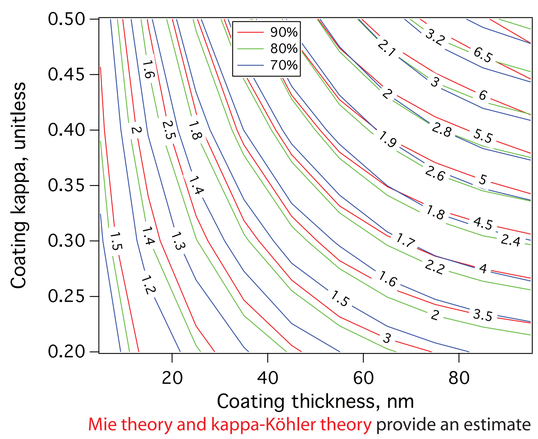
Demonstration of behavior on controlled aerosols: BC with and without water-active coating materials.

One parameter, coating thickness, was optimized to generate the theoretical Humid/dry scattering ratio as a function of RH. Note that the optimized coating thickness was roughly consistent with estimates based on mobility diameter considerations (with obvious simplification of rBC morphology), but was substantially smaller than the dry SP2-generated estimate based on observed scattering cross sections.

Theory



Ratio of humidified to dry scattering is a function only of dry coating thickness and kappa (for a given core mass)



Mie theory and kappa-Köhler theory provide an estimate of the ratio of scattering from BC-cores of a given mass with coatings of specified thickness and kappa (index of refraction of the coating is neglegible). The ratio is indicative of the relative impact of water uptake on BC scattering, and for more thickly coated BC, is strongly dependent on kappa.